Gar Infested by *Argulus* in the Everglades

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Within a period of two weeks beginning June 13, 1965, more than 2,000 Florida spotted gar (*Lepisosteus platyrhincus* De Kay), between 15 to 75 cm in total length and weighing a total of approximately 1,700 pounds, died from a mass infestation by the fish louse (*Argulus* n.sp.) as shown in Figs. 1 and 2. The infestation was limited to Royal Palm Pond, a small, shallow body of water with a surface area of about 33,000 square feet located in Everglades National Park (Figs. 3 and 4). Many parasitized gar, prob-

Fig. 1. Florida spotted gar floating in Royal Palm Pond, dead as result of infestation by *Argulus* n. sp. Photograph by Robert Haugen, National Park Service.

Fig. 2. Fish lice (*Argulus* n. sp.) clinging to the body surface of a Florida spotted gar. Photograph by Robert Haugen, National Park Service.

ably weakened by loss of blood, lay motionless along the edges of the pond until they died. During the height of the infestation adults of *Argulus* were so abundant that several freely swimming individuals could be collected by the sweep of a dip net through the water.

The parasites on the fish were dense during the period of mortality. For example, a count of *Argulus* on three gar yielded the results shown in Table 1.

EFFECTS ON HOST

The hundreds of *Argulus* on each gar in Royal Palm Pond certainly implicate the parasite as the cause of death. By comparison,

TABLE 1
Numbers of *Argulus* n.sp. on Individual Gar

No. *Argulus*	Gar length (cm)	Gar girth (cm)	Date
369	42	16	June 14, 1965
224	38	12	June 17, 1965
508	34	13	June 21, 1965

Wilson (1903) found that in an aquarium as few as 15 or 20 *Argulus catostomi* were sufficient to kill a dace or a bream overnight. While feeding, he states, the parasites remained in position for one hour or more, suggesting that the blood was obtained slowly. Upon the death of its host *Argulus* left the body at once and swam about actively in search of a new victim.

Bauer (1961) listed the detrimental influences that *Argulus* can have upon its host, namely:

1. *Mechanical effects*: *Argulus* pierces the skin of the fish with

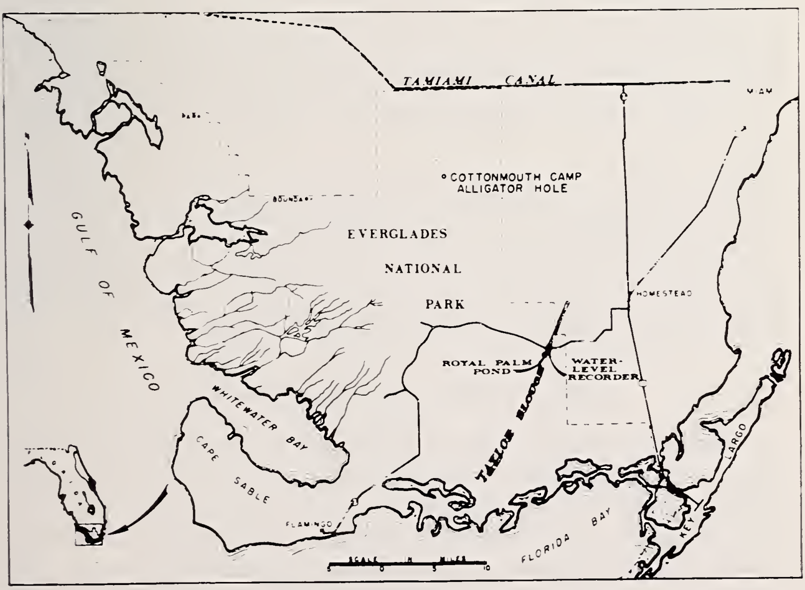

Fig. 3. Map locating Royal Palm Pond and Cottonmouth Camp Alligator Hole in Everglades National Park.

Fig. 4. Aerial view of Royal Palm Pond. Shrubby growth adjacent to the pond is largely willow (*Salix amphibia*).

its modified mouth-parts and sucks blood through the inflicted wound. Tissues are damaged, and protective layers are ruptured.

2. *Toxins*: The mouth armament of *Argulus* includes a poison gland, the secretion of which, in cases of mass infestation, may kill small fish.

3. *Vectors of other parasites*: *Argulus* might act as a vector of parasites as, for example, the red disease of carp.

4. *Parasites as indirect causes of diseases*: By damaging the body surface parasites favor the penetration of pathogenic organisms, mainly bacteria and molds, less often Protozoa.

PAST FISH KILLS IN SOUTH FLORIDA

Whitmoyer (1959) summarized the scanty historical data available on major fish kills in Royal Palm Pond and other areas in south Florida. Past mortalities of fish were unrelated to parasitism and they involved species other than the gar. It is likely that many of these fish kills resulted from insufficient oxygen in the water. For example, he reports a major fish die off in Royal Palm Pond in 1959: "It is estimated that 1,850 pounds of bass, and bream, were hauled away from January 30 to February 3." Whitmoyer consulted with Dr. B. P. Hunt of the University of Miami and C. Loveless of the Florida Game and Fresh Water Fish Commission. They concurred that an oxygen content of less than three ppm (parts per million) was deleterious to most game fishes and that fish die offs in south Florida generally were the result of asphyxiation by hypoxia. In this connection Jones (1964) reviewed the literature on minimum oxygen concentrations for fish. Nine fresh-water fishes, but different from the genera found in the Everglades, required an average minimum dissolved oxygen content of 1.8 ppm for survival at temperatures ranging from 20 to 30°C. Temperatures in the Park generally fall within this range.

Considerable diel fluctuations in oxygen, associated with plankton blooms, often occur in the ponds and alligator holes of the Everglades. For example, at Cottonmouth Camp Alligator Hole in the Park (Fig. 3) the dissolved oxygen near the surface rose to a maximum of 16 mg/l (for practical purposes mg/l, milligrams of oxygen per liter, is interchangeable with ppm) during the day and dropped to a minimum of 0.2 mg/l at night on April 29 and 30, 1965. The alligator hole, similar to but smaller than Royal Palm Pond, had a density of 11 million phytoplankters per liter. Centrarchid fishes such as bass and bream were absent from the alligator hole. Of all the fishes in the Everglades centrarchids are the most sensitive to poorly oxygenated water.

The only pertinent observation of dissolved oxygen at Royal Palm Pond was made in connection with an investigation of an algal bloom that occurred 18 days previous to the massive mortality of gar. On May 26, 1965 at 3 P.M. the oxygen at the edge of the pond measured a few centimeters below the water surface was 23 mg/l. This value, relatively high for any aquatic habitat in south Florida, undoubtedly was related to the population of over 13 million planktonic plants per liter in the pond (Table 2). As a consequence of the combined respiration of animals and plants during the hours of dark and considering the fluctuations in dissolved oxygen at the alligator hole, the oxygen in Royal Palm Pond probably approached zero before daybreak. Probably the average range of fluctuation in dissolved oxygen was even greater in the days that followed until the fish kill by *Argulus* transpired, for in excess of 1 billion phytoplankters per liter were counted on June 14. As a

TABLE 2
Phytoplankton populations at Royal Palm Pond in 1965

	Number of Phytoplankters per Ml		
Phytoplankter	May 26	June 14	June 21
Green algae			
Ankistrodesmus	27.8	6,700	126
Pandorina	368	3,348	31.5
Scenedesmus	2,920	81,100	1,030
Blue-green algae			
Microcystis	2,310	1,670	78.7
Miscellaneous algae			
Unidentified genera	4,240	688,000[a]	449
Green flagellates			
Chlamydomonas	3,310	343,000	362
Unidentified genus	0	16,700	78.7
Diatoms			
Synedra	111	8,370	31.5
Desmids			
Closterium	195	16,700	47.2
TOTALS	13,482	1,165,588	2,235

[a]This figure of unidentified genera is composed largely of spherical algal cells of approximately 3 microns in diameter, occurring singly and in clumps of 2, 3, and 4 cells.

phytoplankton bloom generally involves concentrations of less than several million individuals per liter, a population greater than 1 billion per liter must be considered extremely unusual. By June 21 the number of phytoplankters had receded to approximately 2.2 million per liter (Table 2).

Argulus n. sp. tolerates extreme oxygen fluctuations in the water while more sensitive aquatics die. The Florida spotted gar manages to survive in oxygen-depleted water by air breathing with its lung-like air bladder (Clugston, 1962). The upper tolerable limit of dissolved oxygen for the gar is unknown. However, Woodbury (1941) has shown that fish kills have resulted from a supersaturation of oxygen. He cites a heavy loss of fish accompanied by a dense algal bloom and a high dissolved oxygen content of 30 to 32 ppm in the surface water. Gas emboli were present in the gill capillaries and gas bubbles occurred in the subcutaneous tissues. Apparently the death of the fish resulted from a blocking of the circulation through the gills by the gas.

FACTORS INFLUENCING THE POPULATION EXPLOSION

The most probable factors that influenced the population explosion of *Argulus* n.sp. in Royal Palm Pond were apparently the concentration of gar as hosts and the lack of predators on the parasites.

Abundant Hosts for Argulus. A concentration of approximately one Florida spotted gar per 35 cubic feet of water was present in the pond immediately before the fish kill in May 1965. The lowest water level in the pond since the beginning of record in August 1960 produced this density of gar. Assuming negligible gradient in water level in the 1.5 miles between the recording gauge at Taylor Slough and Royal Palm Pond (Fig. 3), the average depth of the pond in May 1965 was only about 2.1 feet. In comparison, the lowest mean monthly depths of the pond in the dry season of previous years were as follows: May 1961, 3.9 feet; May 1962, 3.0 feet; April 1963, 2.8 feet; and April 1964, 3.8 feet (Fig. 5). These depths exclude a layer of organic ooze and peat having a mean depth of 1.3 feet that covers the limestone basin of the pond. The rainfall in the vicinity of the pond for the first six months of 1965 totaled only 13.6 inches (Fig. 5). This was the lowest semi-annual amount since the last excessive drought in 1956, when only 6.7 inches of precipitation occurred in the same period.

The water level of Royal Palm Pond results from several hydrologic phenomena. Antecedent water levels and the recessions therefrom create a varying water depth in the pond. An increase in flow from the north through Taylor Slough causes the water level in the pond to rise. During the dry season the pond lowering is accelerated by evapotranspiration. Rainfall alone is not an indicator of water levels in the pond for after the precipitation reaches the earth, it is modified by the other factors mentioned above.

An easy accessibility of hosts for *Argulus* resulted from the high concentration of gar. In a parallel situation, Dr. B. P. Hunt (per-

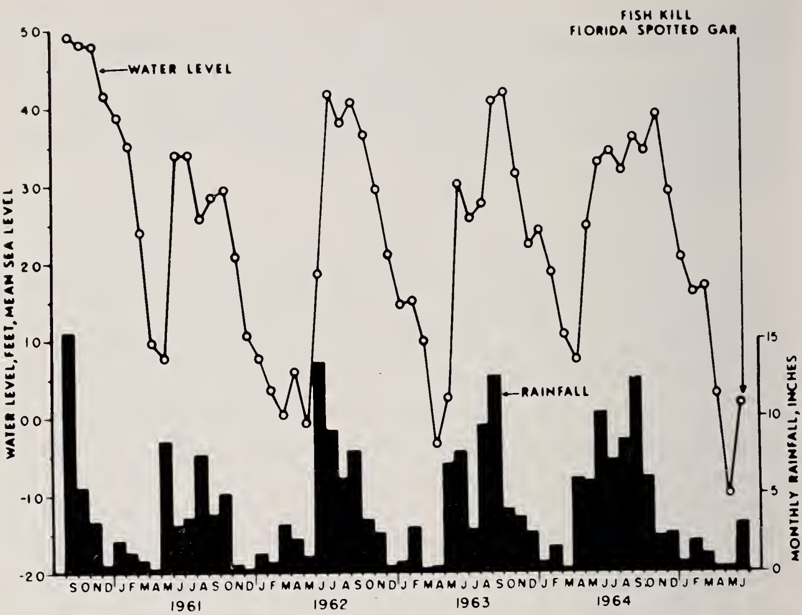

Fig. 5. Mean monthly water levels in Taylor Slough at State Road 27 and rainfall at Royal Palm Ranger Station from September 1960 to June 1965.

sonal communication) observed an increase in *Argulus* (possibly *Argulus* n.sp.), an ectoparasitic copepod (*Lernea* sp.), and fungal infection on gar in the Tamiami Canal from February to June 1957, when water levels were low. At that time a cursory examination of conditions indicated that the numbers of *Argulus* were insufficient to create a mass mortality.

Lack of Predators on Argulus. Few centrarchids, smaller fish, and invertebrates that would ordinarily feed on the larval and adult stages of *Argulus* seemed to be present in Royal Palm Pond in May and June 1965. The limited number of these ordinarily common predators resulted from heavy feeding by the gar and from low oxygen level. Hunt (1952) showed that the diet of Florida spotted gar in Tamiami Canal consisted principally of fish. Of those consumed, mosquitofish (*Gambusia affinis holbrooki*) occurred more frequently than any other fish, followed by redfin killifish (*Lucania goodei*), flagfish (*Jordanella floridae*), centrarchids, least killifish (*Heterandria formosa*), and sailfin molly (*Mol-*

TABLE 3

Results of feeding experiments indicating likely predators of *Argulus* n.sp.

No. of fish in aquarium	Species of fish	No. of *Argulus* consumed
3	Flagfish, *Jordanella floridae*	30 in 28 hours
2	Golden topminnow, *Fundulus chrysotus*	5 in 21 hours
3	Least killifish, *Heterandria formosa*	None in 24 hours
2	Spotfin killifish, *Fundulus confluentus*	None in 24 hours
8	Mosquitofish, *Gambusia affinis*	None in 24 hours
4	Sailfin molly, *Mollienesia latipinna*	None in 24 hours
1	Bullhead catfish, *Ictalurus nebulosus*	None in 48 hours

This table is summarized from notes compiled by John D. Leppert, who conducted the feeding experiments with common fresh water fishes of the Everglades on June 21 and 22, 1965.

The specimen of *I. nebulosus* was 3 inches long. All other fish tested were adults.

lienesia latipinna). Although a variety of invertebrates was consumed, only the fresh-water prawn (*Palaemonetes paludosus*) was of consequence, comprising 16.5 per cent of the total food volume.

Both direct and indirect evidence exists that some of the above species, found in the diet of gar, feed on *Argulus*. Direct confirmation comes from an analysis of stomach contents of animals inhabiting Tamiami Canal (Hunt, 1952), in which *Argulus* occurred in small numbers in the guts of fresh-water prawn and the centrarchids: bluegill (*Lepomis macrochirus*) and spotted sunfish (*Lepomis punctatus*). The consumed animals were possibly *Argulus* n.sp., because specimens collected by Hunt from the Tamiami Canal in the early 1960's definitely belonged to the same taxon.

Leppert (personal communication) demonstrated in laboratory aquaria that the flagfish and golden topminnow (*Fundulus chrysotus*) feed on *Argulus* n.sp. (Table 3). G. Zimmer and E. Christensen of the National Park Service (personal communication) also indicated that in an aquarium the water scorpion (*Ranatra* sp.) feeds on the parasite.

Wilson (1903) describes a fish kill that may be analogous to the kill at Royal Palm Pond, because it resulted from a lack of predators on *Argulus catostomi.* A small pond in Warren, Mass., was artifically increased to a few acres in area by means of a dam. After several years stocked carp and bass began to die off in considerable numbers from an infestation of *A. catostomi.* In addition, the pond proved to harbor myriads of small Crustacea, such as *Daphnia* and *Sida.* The infestation began in summer, lasting through fall and winter. The apparent reason for the fish kill is that in those years previous to the fatality among the fish the proprietor removed essentially all the small dace and roach from the pond and sold them for live bait. These young fish, based on observations in an aquarium, fed on the larval stages of *Argulus.* The *Argulus* and other crustacean populations were apparently unchecked because the predators were removed.

The described mortality of gar affected, at least for some months, the balance in the populations and well-being of many animals that live in and around Royal Palm Pond. The gar is strategically located as a consumer and as a food source in several Everglades food webs. The myriad of small fishes and invertebrates that it feeds upon has already been discussed. The gar, itself, is a staple in the diets of a variety of larger animals, such as the alligator and otter. By the summer of 1966, a year after the fish kill, a few gar had entered the pond by normal movement from nearby ponds and marshes that become interconnected when water levels rise above the ground. By the following summer reasonable numbers of healthy gar were observed in the pond.

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